Influence of water hardness, chloride, and acclimation on the acute toxicity of sulfate to freshwater invertebrates

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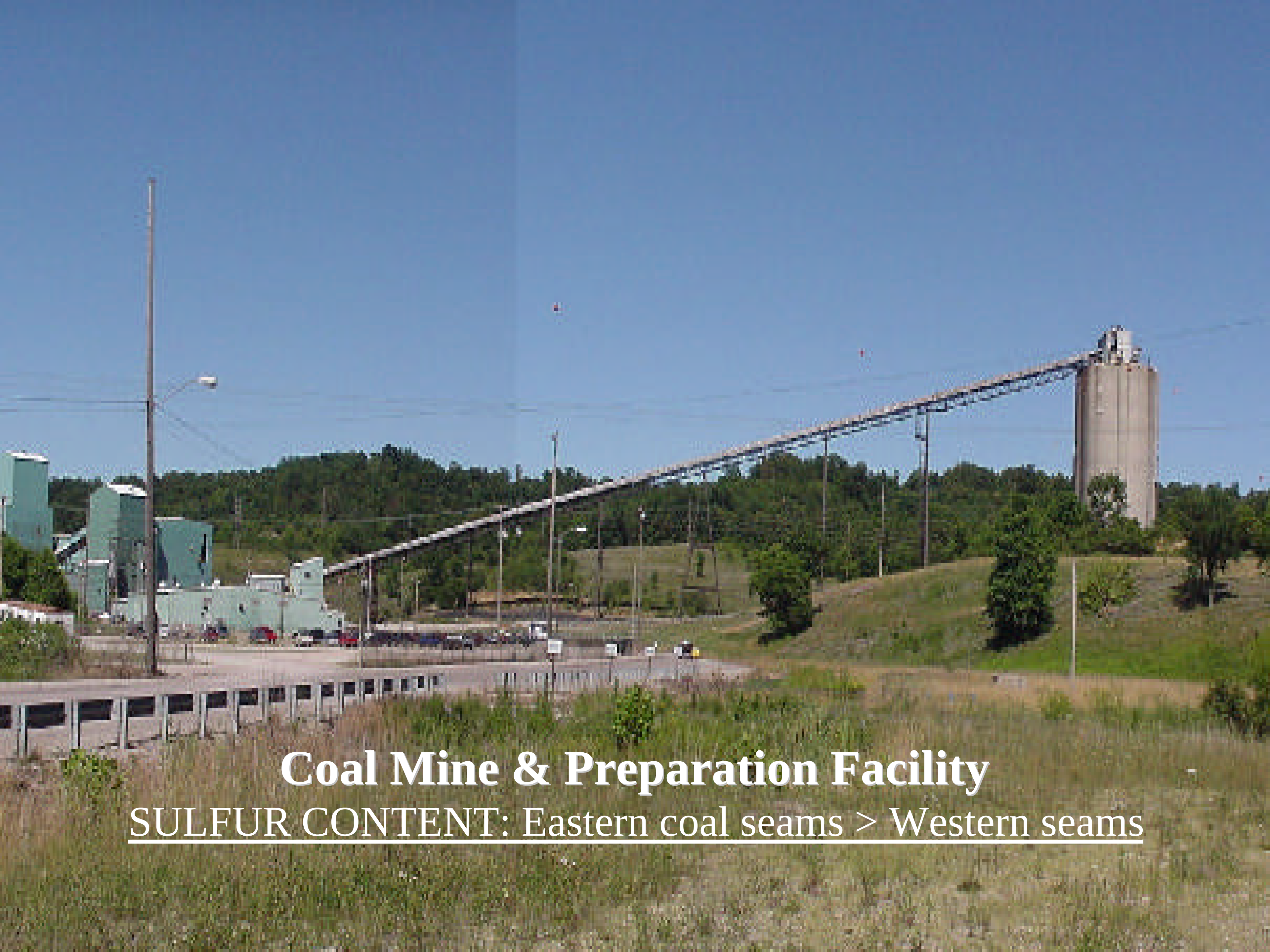


Coal Mine & Preparation Facility

SULFUR CONTENT: Eastern coal seams > Western seams


Parker Run, Ohio
Conductivity ~8100 mS/cm
pH ~ 8.1
Hardness ~800

No current federal aquatic life standard for sulfate

Few States have aquatic life standards for sulfate.

In Illinois, General Use standard is currently 500 mg/L (based on drinking water standard).

Objectives:

1. Generate acute toxicity data for sodium sulfate in MHRW
2. Determine influence of hardness on sulfate toxicity
3. Determine influence of acclimation on sulfate toxicity
4. (Determine influence of chloride on sulfate toxicity)

Ceriodaphnia dubia

Hyalella azteca

Chironomus tentans


Photo: Mike Jeffords, INHS

Sphaerium simile

Toxicity of sulfate to freshwater invertebrates in MHRW (U.S. EPA, 1993). Hardness = 90-100 mg/L. LC50s expressed as mg $\mathbf{SO_4}$/L.

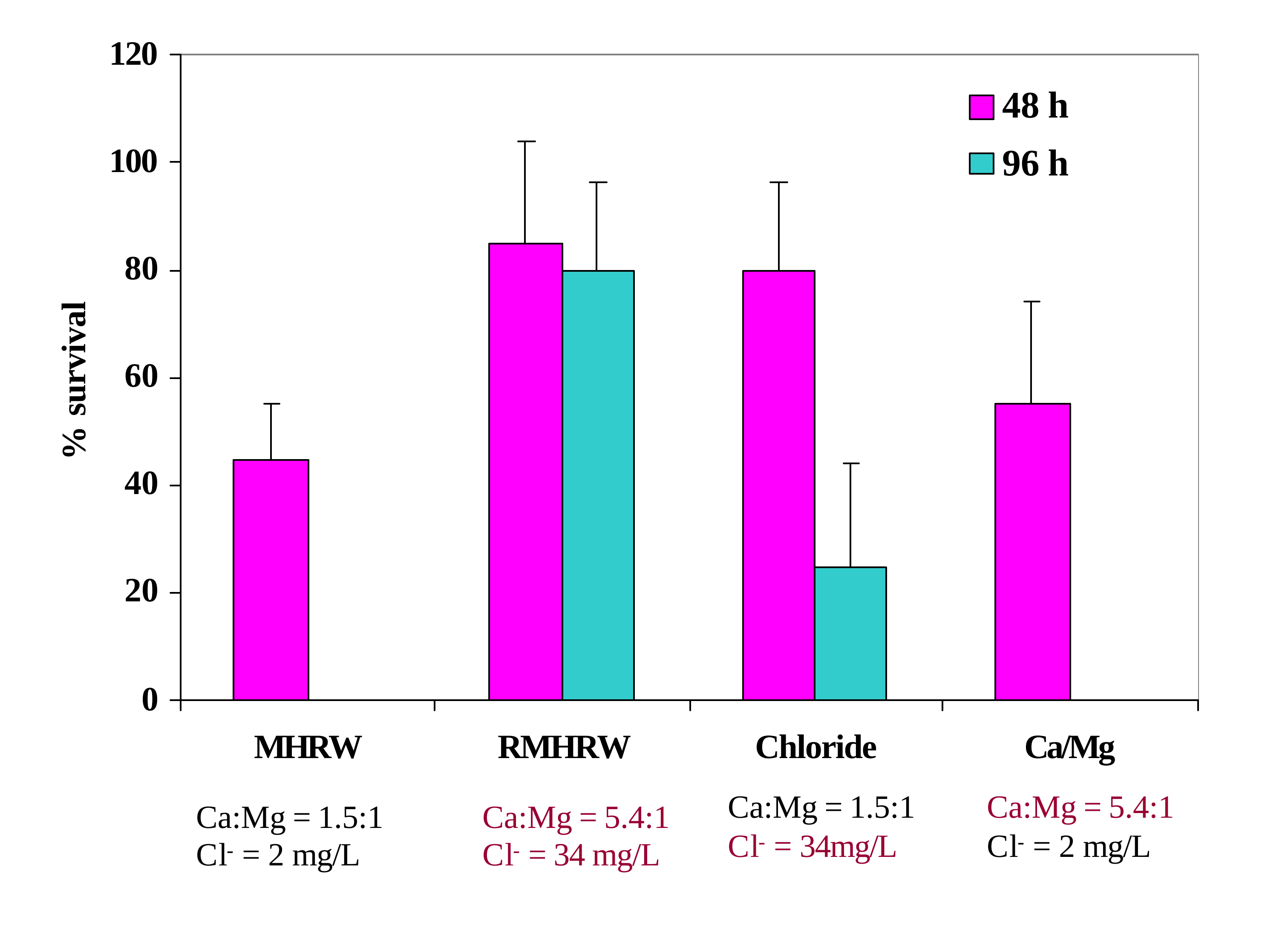
Species	Duration	Temp	Mean LC50	Range	LC10
Ceriodaphnia dubia	**48 h**	**25 °C**	**2,050 mg/L**	**1,869 – 2,270**	**1,759**
***Ceriodaphnia dubia* (Mount et al., 1997)**	**48 h**	**25 °C**	**2,082 mg/L**	**1,196 – 2,392**	**N/A**
Chironomus tentans	**48 h**	**22 °C**	**14,134 mg/L**	**14,123 - 14,146**	**11,682**
Sphaerium simile	**96 h**	**22 °C**	**2,078 mg/L**	**1,901 - 2,319**	**1,502**
Hyalella azteca	**96 h**	**22 °C**	**512 mg/L**	**431 - 607**	**262**

Nominal chemical composition of MHRW (U.S. EPA, 1993) and RMHRW (Smith et al., 1997)

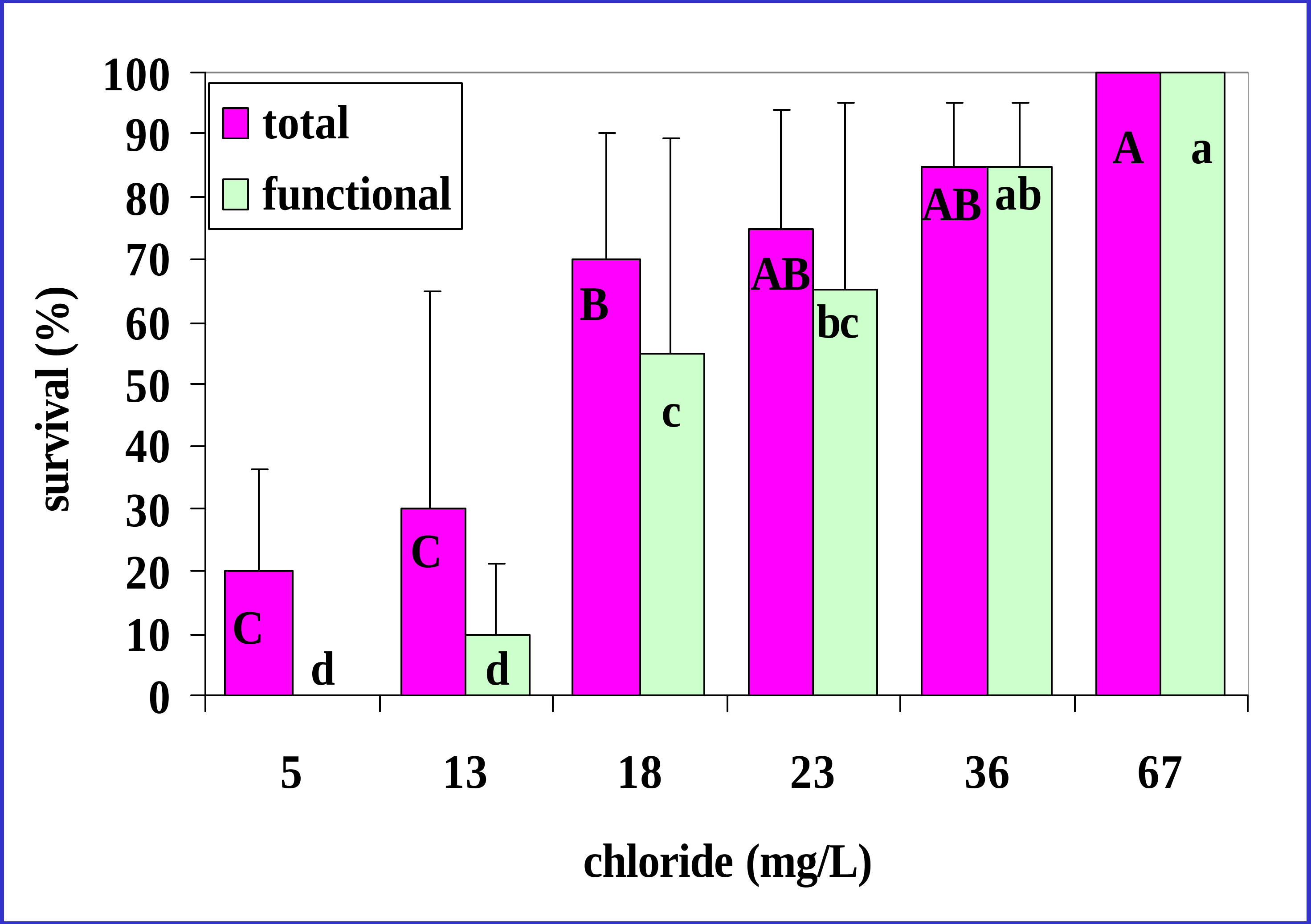
Component	MHRW	RMHRW
K^{+} (mg/L)	2.1	2.1
Na^{+} (mg/L)	26.3	26.3
Ca^{2+} (mg/L)	17.6	32.7
Mg^{2+} (mg/L)	12.1	6.1
SO_4^{2-} (mg/L)	90.2	59.2
Cl^{-} (mg/L)	1.9	33.9
HCO_3^{-} (mg/L)	69.7	69.7
hardness (mg/L as $CaCO_3$)	94	107
Ca/Mg	1.46	5.40
pH	7.9	7.9
conductivity (ìS/cm)	295	341

Influence of culture/testing water composition on toxicity of sulfate to *Hyalella azteca* and *Ceriodaphnia dubia*.
LC50s expressed as mg **SO_4**/L.

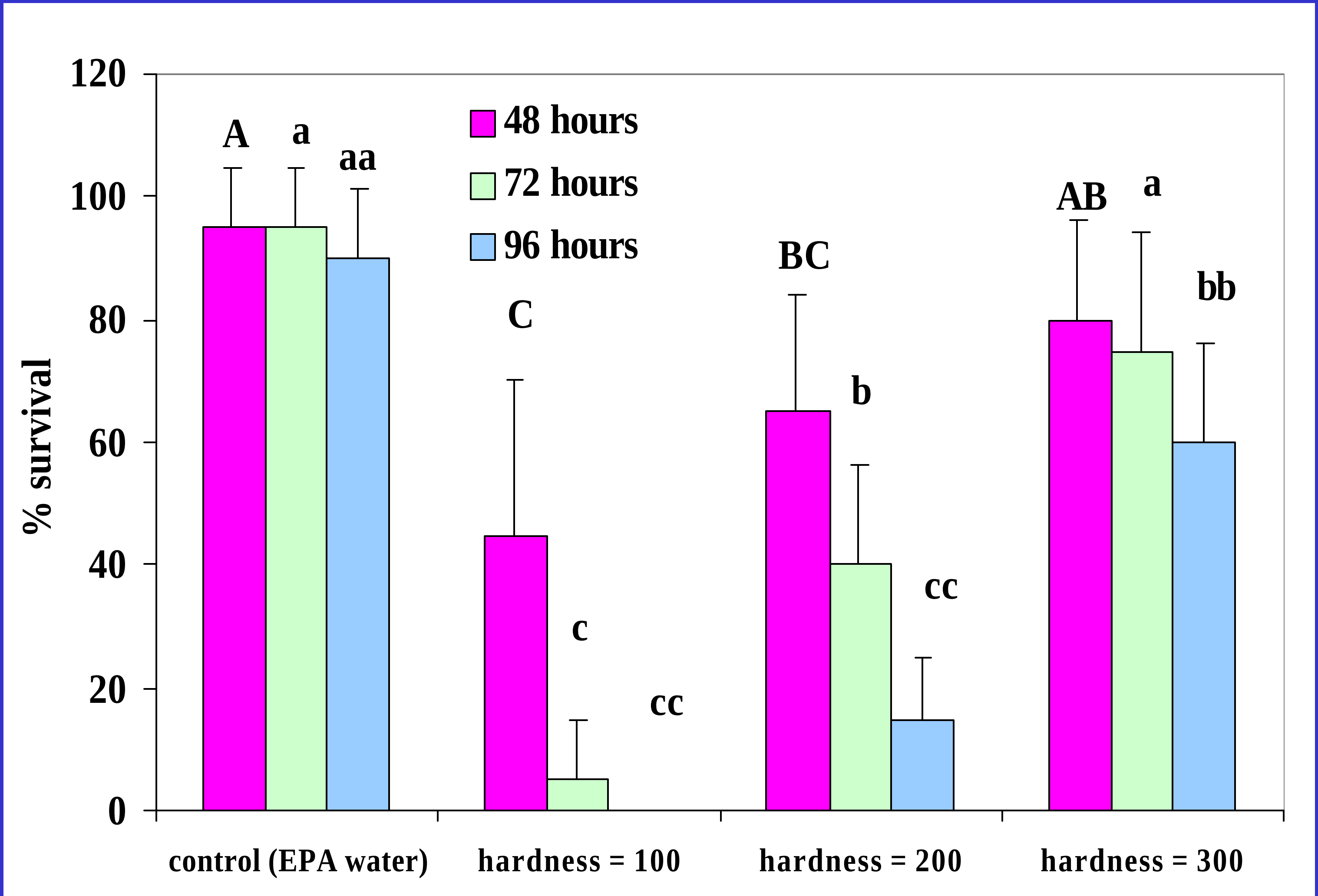
Species	Water type	hardness	Ca:Mg	Chloride	LC50	LC10
H. azteca	**MHRW**	**90**	**1.46:1**	**2 mg/L**	**512 mg/L**	**262 mg/L**
H. azteca	**RMHRW**	**106**	**5.40:1**	**34 mg/L**	**2,855* mg/L**	**2,185 mg/L**
C. dubia	**MHRW**	**90**	**1.46:1**	**2 mg/L**	**2,050 mg/L**	**1,759 mg/L**
C. dubia	**RMHRW**	**106**	**5.40:1**	**34 mg/L**	**2,526* mg/L**	**2,216 mg/L**



Effect of various components of RMHRW on survival of *Hyalella azteca* in elevated (**2,500 mg SO_4/L**) sulfate solutions. The "Chloride" and "Ca/Mg" treatments consisted of standard MHRW with chloride or Ca/Mg ratio adjusted to match RMHRW.



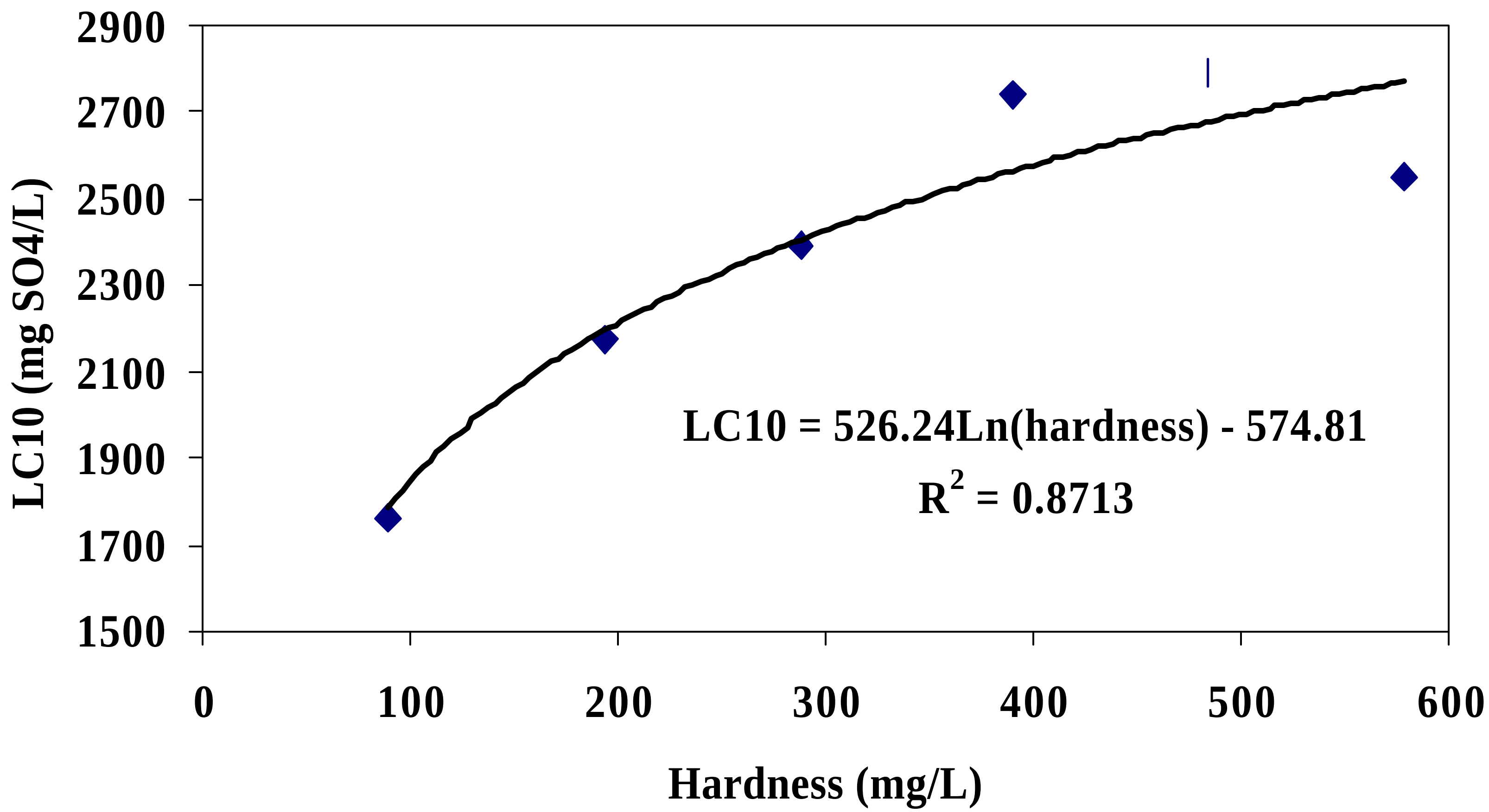
Effect of increasing chloride concentrations on the toxicity of sulfate to *Hyalella azteca*. Mean (±SD) sulfate concentration for all treatments was **2,846 ± 80 mg SO_4^{2-}/L**, mean hardness was 106 ± 2 mg/L as $CaCO_3$, and Ca:Mg was 5.4:1.



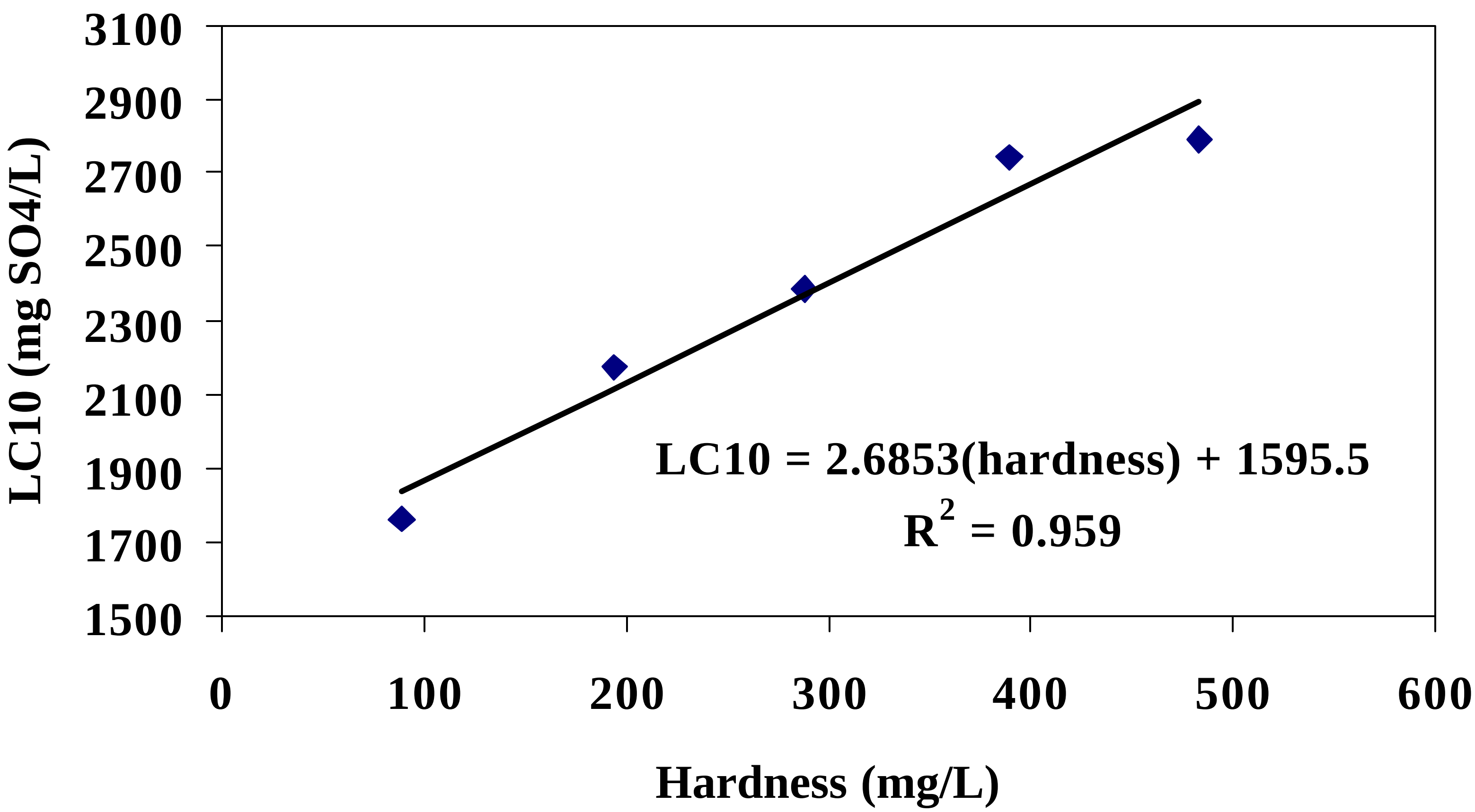
Effect of hardness on toxicity of elevated sulfate to *Hyalella* in **MHRW**. Average measured **sulfate concentration was 1,460 mg/L** (S.D. = 25) for the three treatments excluding the control (106 mg/L sulfate).

Influence of water hardness on toxicity of sulfate to *Ceriodaphnia dubia* in MHRW. All tests were conducted at 25 C for 48 hours. LC50s expressed as mg **SO_4**/L. Ca:Mg for all treatments was 1.46:1

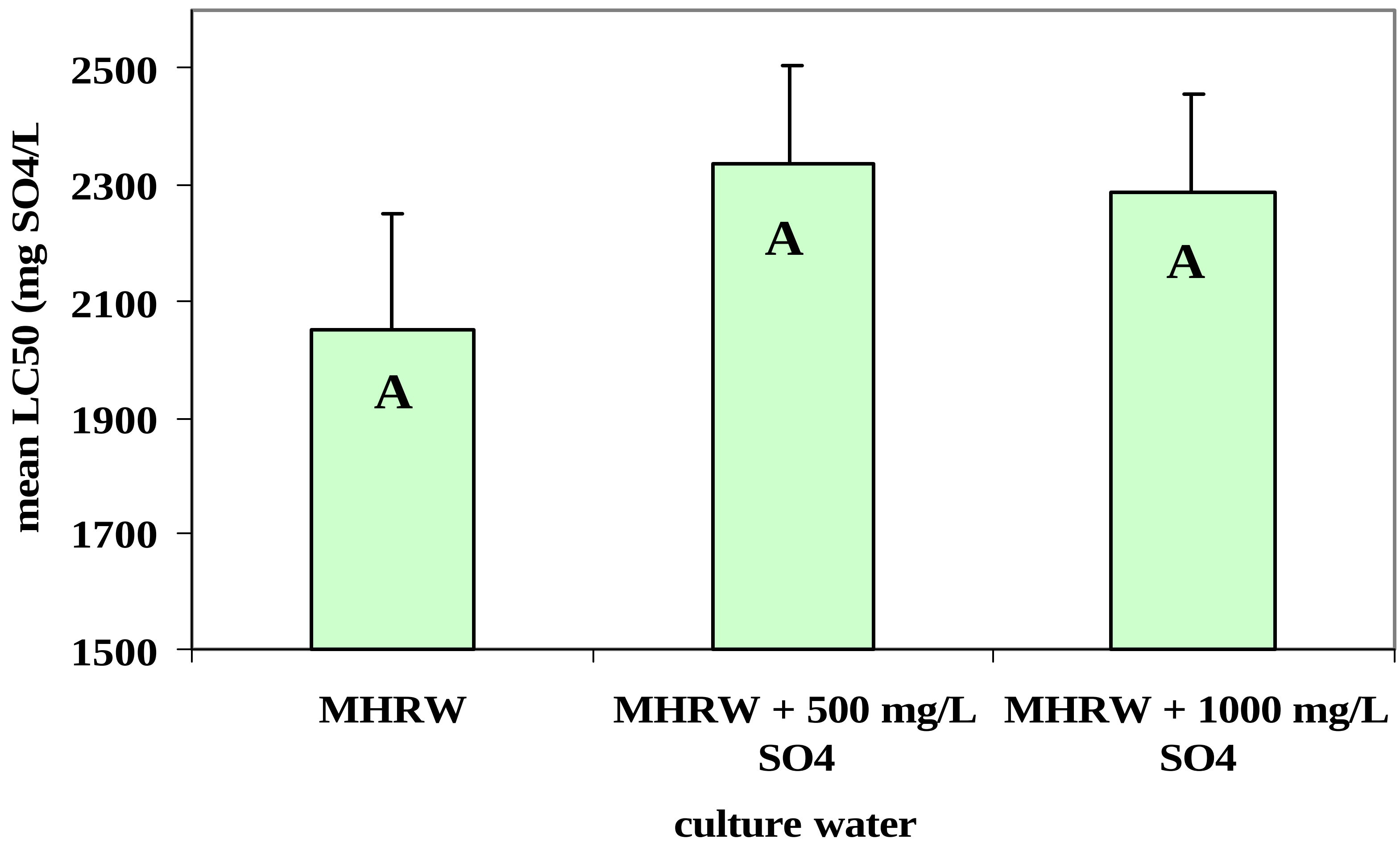
Hardness	n	Mean LC50	LC50 Range	LC10	LC10 95% C.I.
90 (89)	3	2,050	1,869 – 2,270	1,759	1,365 - 1,929
200 (194)	3	3,000	2,706 – 3,265	2,173	388 – 2,686
300 (288)	4	2,946	2,383 – 3,361	2,389	1,752 – 2,668
400 (390)	3	3,174	3,073 – 3,369	2,744	2,190 – 2,997
500 (484)	3	3,516	3,338 – 3,716	2,793	2,519 – 2,989
600 (578)	3	3,288	2,761 – 4,220	2,547	1,006 – 3,038



Relationship between water hardness and toxicity of sulfate to *Ceriodaphnia dubia* (48-h LC10 values are shown).



Relationship between water hardness and toxicity of sulfate to *Ceriodaphnia dubia* (48-h LC10 values are shown).



Effect of acclimation on toxicity of sulfate to *Ceriodaphnia dubia*. Organisms were cultured for at least three generations in MHRW, MHRW with 500 mg SO_4^{2-}, or MHRW with 1000 mg SO_4^{2-}.

Conclusions

•Sensitivity to sulfate in MHRW: *Hyalella* > *Ceriodaphnia* = *Sphaerium* > *Chironomus*

•Increased chloride reduced toxicity of sulfate to *Hyalella* and *Ceriodaphnia*.

•Increased hardness reduced toxicity of sulfate to *Hyalella* and *Ceriodaphnia*. Calcium probably more important than magnesium.

•Acclimation of *Ceriodaphnia* to 500 and 1000 mg SO_4^{2-}/L resulted in nominally higher LC50s compared to unacclimated organisms.

Acknowledgements

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